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ABSTRACT

This document is an instructional module prepared in objective form for use by an instructor familiar with mathematics as applied to water and wastewater treatment plant operation. Included are objectives, instructor guides and student handouts. This is the third level of a three module series and is concerned with statistics, total head, steady flow in pipes, flow measurement and pump motor power and efficiency. (Author/BB)

ADVANCED MATHEMATICS

Training Module 1.303.3.77

Prepared for the

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Des Moines, Iowa 50319

by

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September, 1977

SUMMARY

Module No:	Module Title: Advanced Mathematics
Approx. Time: 14 hours	Submodule Titles: a. Review b. Statistics c. Total head d. Steady flow in pipes e. Flow measurement f. Pump motor power and efficiency

Overall Objective:

Upon completion of this module the learner should be able to use the principles of mathematics of addition, subtraction, multiplication, division and to use specific formulas as applied to water and wastewater technology.

Instructional Aids:

Handout
AV (overhead transparency)
Calculators

Instructional Approach:

Discussion
Demonstration
Exercise

References:

Manual of Water Utility Operations, Texas Water Utilities Association.

Mathematics for Water and Wastewater Treatment Plant Operators, Kirkpatrick, Ann Arbor Science.

Class Assignments:

1. Given handout to be read
2. Given exercise problems to be solved
3. Given evaluation problems to be solved

Module No:	Topic: Advanced Mathematics

Instructor Notes:	Instructor Outline:
1. Give handout of each submodule 2. Allow sufficient time or exercise problems to be solved. 3. Review exercise problems. 4. Give evaluation problems.	Discuss/demonstrate using the students handout how one uses formulas as applied to water and wastewater technology in a. Statistics b. Total head c. Steady flow in pipes d. Flow measurement e. Pump and motor efficiency

Module No:	Module Title: Advanced Mathematics
	Submodule Title:
Approx. Time: 2 hours	Topic: Review

Objectives:

The learner will demonstrate the ability to determine the answer to problems related to

1. Detention time
2. Hydraulic loading
3. Organic loading
4. Efficiency
5. Conversion of concentration (mg/l) to pounds/day

Instructional Aids:

Handout
AV (overhead transparency)

Instructional Approach:

Discussion
Demonstration
Exercise

References:

Manual of Water Utilities Operation, Texas Water Utilities Association.

Mathematics for Water and Wastewater Treatment Plant Operators, Kirkpatrick, Ann Arbor Science.

Class Assignments:

Given exercise problems to be solved

Module No:	Topic: Review

Instructor Notes:	Instructor Outline:
	Discuss/demonstrate the use of formulas
	1. Areas
	a. Circle πR^2
	b. Rectangle/square L x W
	c. Triangle 1/2 b x h
	2. Volumes
	a. Cylinder πR^2 x H
	b. Rectangular solid/cube L x W x H
	c. Pyramid/cone 1/3 π x R^2 x H
	3. Conversion of concentration (mg/l) to pounds/day
Q - flow rate Indicate that Q could also be volume of a tank. Unit value of Q is ~~in~~ MG	lbs/day = mg/l x 8.34 x Q
	4. Hydraulic loading
	$HL = \frac{Q}{SA}$
Indicate that solids could be a. BOD b. COD c. TS. S. d. T. VSS e. Ts. f. TVS	5. Organic loading
	$OL = \frac{\text{lbs. of solid}}{\text{Volume of unit}}$
	6. Percentage = Parts of 100 parts
	7. Efficiency = $\frac{\text{in - out}}{\text{In}}$ x 100

Module No:	Topic: Review

Instructor Notes:	Instructor Outline:
Ans. DT = 2 Hrs. SSR = 1,202.94 GPD/$ft.^2$ HL (T.F.) = 344 GPD/$ft.^2$ OL (T.F.) = 61.18 lbs. BOD/ 1,000 cu. ft. Lbs. of Cl_2 = 101.84 lbs/day BOD Eff. = 93% SS. Eff. = 92%	Give one exercise problem that combines several of the principles discussed above.

REVIEW

I. Areas

A. Circles: The area of a circle is

$A = \pi \times R^2$ — $\pi = 3.14$

R = Radius of the circle

B. Rectangle/Square: The area of a rectangle/square is

$A = L \times W$ — L = Length

W = Width

C. Triangle: The area of a triangle is

$A.$ $1/2\ b \times h$ — b = Base

h = Height

II. Volumes

A. Cylinder: The volume of a cylinder is

$V = \pi \times R^2 \times H$ — $\pi = 3.14$

R = Radius of circle

H = Height or length of cylinder

B. Rectangle Solid/Cube: The volume of a ractangular/cube is

$V = L \times W \times H$ — L = Length

W = Width

H = Height or depth

C. Sphere: The volume of a sphere is

$V = 4/3 \pi \times R^3$ — $\pi = 3.14$

R = Radius of sphere

D. Pyramid: The volume of the pyramid is determined by the

V = 1/3 area of base x height

The most common pyramid used in ~~water and wastewater~~ technology is a cone. The volume of a cone is

$V = 1/3 \times \pi \times R^2 \times H$

$\pi = 3.14$

R = Radius of circle

H = Height/depth of cone

III. Conversion of concentration (mg/l) to pounds/day. The formula to use is

lbs/day = mg/l x 8.34 x Q

Q = Flow rate

IV. Hydraulic Loading: The formula to use for hydraulic loading is

$HL = \frac{Q}{SA}$

HL = Hydraulic loading

Q = Flow rate

SA = Surface area of unit

V. Organic Loading: The formula to use for organic loading is

$OL = \frac{\text{lbs. of organic solids}}{\text{Volume of unit}}$

OL = Organic Loading

Lbs. of organic solids = lbs. of (a) BOD or

(b) COD or

(c) Suspended solids or

(d) Volatile suspended solids or

(e) Total solids ~~or~~

(f) Total volatile solids

Volume of unit = Volume of process unit

VI. Percentage: Percent is defined as portion of 100

Ex. 3% = 3 parts of 100 parts or

60% = 60 parts of 100 parts

VII. Efficiency: In water and wastewater technology, efficiency (in most cases) is an indication of the % removal of "pollutants" in a process. The formula to use is

$$\% \text{ Eff.} = \frac{\text{In} - \text{Out}}{\text{In}} \times 100$$

In = Amount of "pollutants" in influent to the unit

Out = Amount of "pollutants" left in the effluent from the unit

Exercise

Given

Flow rate - 1,200 GPM for 24 Hrs.

BOD influent - 300 mg/l

primary effluent - 150 mg/l

final effluent - 20 mg/l

Suspended solids (SS) influent - 250 mg/l

primary effluent 100 mg/l

final effluent - 20 mg/l

Chlorine - final effluent

dose - 7.1 mg/l

residual - 0.5 mg/l

Primary clarifier

Length - 54 ft.

Width - 27 ft.

Height - 12 ft.

Trickling filter

Diameter - 80 ft.

Media depth - 7 ft.

Determine...

1. Detention time in primary clarifier ________ hrs.
2. Surface settling rate in primary clarifier ________ FPD/ft.^{2}
3. Hydraulic loading on trickling filter ________ GPD/ft.^{2}
4. Organic (BOD) loading on trickling filter ________ lbs. BOD/1,000 cu. ft.
5. Lb. of Cl_2 needed per day ________ lbs./day
6. BOD efficiency of the plant ________ %
7. S. S. efficiency of the plant ________ %

Module No:	Module Title: Mathematics
	Submodule Title: Statistics
Approx. Time: 2 hours	Topic: Geometric Mean

Objectives:

The learner will demonstrate the ability to determine the geometric mean of a group of numbers using logarithm and anti-logarithm tables.

Instructional Aids:

Logarithm tables
Handout
AV (overhead transparancy)

Instructional Approach:

Discussion
Demonstration
Exercise

References:

Handbook of Mathematical Tables and Formulas, Handbook Publishers Inc., Sandusky, Ohio

Class Assignments:

Give 13 exercise problems to be solved

Module No:	Topic: Geometric Mean

Instructor Notes:	Instructor Outline:
1. Handout a. Explain 1. Characteristics of a number 2. Mantissa	1. Discuss and demonstrate how one calculates geometric mean of a group of numbers using natural logarithums Formula: Determine the antilog of the value obtained by dividing the sum of logarithums of group of numbers by the number of groups. 2. Give 6 exercise problems.

—*Common logarithms of numbers*—

N.	L. 0	1	2	3	4	5	6	7	8	9
10	00 000	00 432	00 860	01 284	01 703	02 119	02 531	02 938	03 342	03 748
11	04 139	04 532	04 922	05 308	05 690	06 070	06 446	06 819	07 188	07 555
12	07 918	08 279	08 636	08 991	09 342	09 691	10 037	10 380	10 721	11 059
13	11 394	11 727	12 057	12 385	12 710	13 033	13 354	13 672	13 988	14 301
14	14 613	14 922	15 229	15 534	15 836	16 137	16 435	16 732	17 026	17 319
15	17 609	17 898	18 184	18 469	18 752	19 033	19 312	19 590	19 866	20 140
16	20 412	20 683	20 952	21 219	21 484	21 748	22 011	22 272	22 531	22 789
17	23 045	23 300	23 553	23 805	24 055	24 304	24 551	24 797	25 042	25 285
18	25 527	25 768	26 007	26 245	26 482	26 717	26 951	27 184	27 416	27 646
19	27 875	28 103	28 330	28 556	28 780	29 003	29 226	29 447	29 667	29 885
20	30 103	30 320	30 535	30 750	30 963	31 175	31 387	31 597	31 806	32 015
21	32 222	32 428	32 634	32 838	33 041	33 244	33 445	33 646	33 846	34 044
22	34 242	34 439	34 635	34 830	35 025	35 218	35 411	35 603	35 793	35 984
23	36 173	36 361	36 549	36 736	36 922	37 107	37 291	37 475	37 658	37 840
24	38 021	38 202	38 382	38 561	38 739	38 917	39 094	39 270	39 445	39 620
25	39 794	39 967	40 140	40 312	40 483	40 654	40 824	40 993	41 162	41 330
26	41 497	41 664	41 830	41 996	42 160	42 325	42 488	42 651	42 813	42 975
27	43 136	43 297	43 457	43 616	43 775	43 933	44 091	44 248	44 404	44 560
28	44 716	44 871	45 025	45 179	45 332	45 484	45 637	45 788	45 939	46 090
29	46 240	46 389	46 538	46 687	46 835	46 982	47 129	47 276	47 422	47 567
30	47 712	47 857	48 001	48 144	48 287	48 430	48 572	48 714	48 855	48 996
31	49 136	49 276	49 415	49 554	49 693	49 831	49 969	50 106	50 243	50 379
32	50 515	50 651	50 786	50 920	51 055	51 188	51 322	51 455	51 587	51 720
33	51 851	51 983	52 114	52 244	52 375	52 504	52 634	52 763	52 892	53 020
34	53 148	53 275	53 403	53 529	53 656	53 782	53 908	54 033	54 158	54 283
35	54 407	54 531	54 654	54 777	54 900	55 023	55 145	55 267	55 388	55 509
36	55 630	55 751	55 871	55 991	56 110	56 229	56 348	56 467	56 585	56 703
37	56 820	56 937	57 054	57 171	57 287	57 403	57 519	57 634	57 749	57 864
38	57 978	58 092	58 206	58 320	58 433	58 546	58 659	58 771	58 883	58 995
39	59 106	59 218	59 329	59 439	59 550	59 660	59 770	59 879	59 988	60 097
40	60 206	60 314	60 423	60 531	60 638	60 746	60 853	60 959	61 066	61 172
41	61 278	61 384	61 490	61 595	61 700	61 805	61 909	62 014	62 118	62 221
42	62 325	62 428	62 531	62 634	62 737	62 839	62 941	63 043	63 144	63 246
43	63 347	63 448	63 548	63 649	63 749	63 849	63 949	64 048	64 147	64 246
44	64 345	64 444	64 542	64 040	64 738	04 836	64 933	65 031	65 128	65 225
45	65 321	65 418	65 514	65 610	65 706	65 801	65 896	65 992	66 087	66 181
46	66 276	66 370	66 464	66 558	66 652	66 745	66 839	66 932	67 025	67 117
47	67 210	67 302	67 394	67 486	67 578	67 669	67 761	67 852	67 943	68 034
48	68 124	68 215	68 305	68 395	68 485	68 574	68 664	68 753	68 842	68 931
49	69 020	69 108	69 197	69 285	69 373	69 461	69 548	69 636	69 723	69 810
50	69 897	69 984	70 070	70 157	70 243	70 329	70 415	70 501	70 586	70 672
N.	L. 0	1	2	3	4	5	6	7	8	9

TM 5-236
War Department July 10, 1940

—*Common logarithms of numbers*—

N.	L. 0	1	2	3	4	5	6	7	8	9
50	69 897	69 984	70 070	70 157	70 243	70 329	70 415	70 501	70 586	70 672
51	70 757	70 842	70 927	71 012	71 096	71 181	71 265	71 349	71 433	71 517
52	71 600	71 684	71 767	71 850	71 933	72 016	72 099	72 181	72 263	72 346
53	72 428	72 509	72 591	72 673	72 754	72 835	72 916	72 997	73 078	73 159
54	73 239	73 320	73 400	73 480	73 560	73 640	73 719	73 799	73 878	73 957
55	74 036	74 115	74 194	74 273	74 351	74 429	74 507	74 586	74 663	74 741
56	74 819	74 896	74 974	75 051	75 128	75 205	75 282	75 358	75 435	75 511
57	75 587	75 664	75 740	75 815	75 891	75 967	76 042	76 118	76 193	76 268
58	76 343	76 418	76 492	76 567	76 641	76 716	76 790	76 864	76 938	77 012
59	77 085	77 159	77 232	77 305	77 379	77 452	77 525	77 597	77 670	77 743
60	77 815	77 887	77 960	78 032	78 104	78 176	78 247	78 319	78 390	78 462
61	78 533	78 604	78 675	78 746	78 817	78 888	78 958	79 029	79 099	79 169
62	79 239	79 309	79 379	79 449	79 518	79 588	79 657	79 727	79 796	79 865
63	79 934	80 003	80 072	80 140	80 209	80 277	80 346	80 414	80 482	80 550
64	80 618	80 686	80 754	80 821	80 889	80 956	81 023	81 090	81 158	81 224
65	81 291	81 358	81 425	81 491	81 558	81 624	81 690	81 757	81 823	81 889
66	81 954	82 020	82 086	82 151	82 217	82 282	82 347	82 413	82 478	82 543
67	82 607	82 672	82 737	82 802	82 866	82 930	82 995	83 059	83 123	83 187
68	83 251	83 315	83 378	83 442	83 506	83 569	83 632	83 696	83 759	83 822
69	83 885	83 948	84 011	84 073	84 136	84 198	84 261	84 323	84 386	84 448
70	84 510	84 572	84 634	84 696	84 757	84 819	84 880	84 942	85 003	85 065
71	85 126	85 187	85 248	85 309	85 370	85 431	85 491	85 552	85 612	85 673
72	85 733	85 794	85 854	85 914	85 974	86 034	86 094	86 153	86 213	86 273
73	86 332	86 392	86 451	86 510	86 570	86 629	86 688	86 747	86 806	86 864
74	86 923	86 982	87 040	87 099	87 157	87 216	87 274	87 332	87 390	87 448
75	87 506	87 564	87 622	87 679	87 737	87 795	87 852	87 910	87 967	88 024
76	88 081	88 138	88 195	88 252	88 309	88 366	88 423	88 480	88 536	88 593
77	88 649	88 705	88 762	88 818	88 874	88 930	88 986	89 042	89 098	89 154
78	89 209	89 265	89 321	89 376	89 432	89 487	89 542	89 597	89 653	89 708
79	89 763	89 818	89 873	89 927	89 982	90 037	90 091	90 146	90 200	90 255
80	90 309	90 363	90 417	90 472	90 526	90 580	90 634	90 687	90 741	90 795
81	90 849	90 902	90 956	91 009	91 062	91 116	91 169	91 222	91 275	91 328
82	91 381	91 434	91 487	91 540	91 593	91 645	91 698	91 751	91 803	91 855
83	91 908	91 960	92 012	92 065	92 117	92 169	92 221	92 273	92 324	92 376
84	92 428	92 480	92 531	92 583	92 634	92 686	92 737	92 788	92 840	92 891
85	92 942	92 993	93 044	93 095	93 146	93 197	93 247	93 298	93 349	93 399
86	93 450	93 500	93 551	93 601	93 651	93 702	93 752	93 802	93 852	93 902
87	93 952	94 002	94 052	94 101	94 151	94 201	94 250	94 300	94 349	94 399
88	94 448	94 498	94 547	94 596	94 645	94 694	94 743	94 792	94 841	94 890
89	94 939	94 988	95 036	95 085	95 134	95 182	95 231	95 279	95 328	95 376
90	95 424	95 472	95 521	95 569	95 617	95 665	95 713	95 761	95 809	95 856
91	95 904	95 952	95 999	96 047	96 095	96 142	96 190	96 237	96 284	96 332
92	96 379	96 426	96 473	96 520	96 567	96 614	96 661	96 708	96 755	96 802
93	96 848	96 895	96 942	96 988	97 035	97 081	97 128	97 174	97 220	97 267
94	97 313	97 359	97 405	97 451	97 497	97 543	97 589	97 635	97 681	97 727
95	97 772	97 818	97 864	97 909	97 955	98 000	98 046	98 091	98 137	98 182
96	98 227	98 272	98 318	98 363	98 408	98 453	98 498	98 543	98 588	98 632
97	98 677	98 722	98 767	98 811	98 856	98 900	98 945	98 989	99 034	99 078
98	99 123	99 167	99 211	99 255	99 300	99 344	99 388	99 432	99 476	99 520
99	99 564	99 607	99 651	99 695	99 739	99 782	99 826	99 870	99 913	99 957
100	00 000	00 043	00 087	00 130	00 173	00 217	00 260	00 303	00 346	00 389
N.	L. 0	1	2	3	4	5	6	7	8	9

GEOMETRIC MEAN

To be able to determine geometric mean one should be able to use common logarithm tables.

The common logarithm of a number consists of two sections:

A. The characteristic

1. The characteristic of any number greater than one (1) is one (1) less than the number of digits before the decimal point.

2. The characteristic of a number less than one (1) is formed by subtracting from 9 the number of zeros (0) between the decimal point and the first significant digit, and writing (- 10) after the log has been determined.

Example 1

Find the characteristic of 235.0

Solution 1

2 3 5 . 0

a. The total number of digits is 3

b. 3 - 1 = 2 = characteristics

Example 2

Find the characteristic of 0.00054

Solution 2

0 . 0 0 0 5 2 4

a. The total number of zero is 3

b. 9 - 3 = 7

The characteristic of .000524 is 7. ..... - 10

B. The MANTISSA

The mantissa of a number is the number obtained from the logarithm tables supplied with this module.

In "reading" the logarithm tables

a. In the column marked N (left hand column) locate the first two digits of the number and pick the column headed by the third digit. The Mantissa is the number appearing at the intersection of the row and column corresponding to the number.

Example 1

Find the Mantissa of the number 213

Solution 1

(Use log tables provided)

a, Locate in column (N) the number 21

b. Move to column (3)

NOTE: NOT THE THIRD COLUMN

Where Row 21 and Column 3 intersect the number is 32838 (the Mantissa)

Example 2

Find the Mantissa of number 0.00321

Solution 2

a. Locate in column (N) the number 32

b. Move to column (1). The intersection of Row 32 and Column 1 is 49276 (the Mantissa)

By combining the characteristic and the Mantissa the logarithm of a number is determined.

Example 1

Find the log of 122

Solution 1

Log 122 = 2.08636

Example 2

Find the log of 0.00263

Solution 2

Log 0.00263 = 7.41996 - 10

To determine the geometric mean of a group of numbers

a. Find the logarithm of each of the numbers

b. Add the logarithm numbers together

c. Divide the total sum by the total number of "numbers"

d. Determine the anti-log that the number obtained in (C)

To determine the anti-log of a number the reverse of the procedure to determine the log of a number is performed.

That is find the Mantissa in the tables. Then the row in column (N) is the 1st and 2nd digit and the column is the third digit.

Example

Find the anti-log of 3.56937

Solution

Locate in log table number 56937 at that number Row 37 and Column 1 intersect. Therefore the number is 371.

The characteristic is 3. Therefore the number is a 4 digit number.

The anti-log of 3.56937 is 3710

Exercise

Find the log to

1. 352
2. 861
3. 2511
4. .0135
5. .00225

Find the anti-log to

1. 3.60206
2. 1.38917
3. 9.4404 - 10
4. 6.38202 - 10
5. 1.0

Exercise for geometric mean

Find the geometric mean of

1. 63500, 31800000, 165000
2. 350, 540, 180, 170, 220
3. 2450, 141000, 1320000, 28

Module No:	Module Title: Advanced Mathematics
	Submodule Title: Statistics
Approx. Time: 1 hour	EVALUATION

Objectives:

Given logarithm tables the learner will demonstrate the ability to determine correctly the answers to 6 out of 8 problems related to

a. Use of logarithm tables

b. Geometric mean

1. Find the log of 154.0

   a. 2.18752

   b. 2.06070

   c. 3.18752

   d. 1.0670 - 10

2. Find the log of 16.30

   a. 1.06446

   b. 1.21219

   c. 1.21219 - 10

   d. 2.21219

3. Find the log of .0000388

   a. 7.94569 - 10

   b. 6.58883 - 10

   c. 4.58883 - 10

   d. 5.58883 - 10

4. Find the anti-log of 9.71933 - 10

a. .0514

b. .514

c. 5.14

d. .827

5. Lab results on fecal coliform are month

Jan. 3,850,000

Feb. 2,660,000

March 550,000

Calculate the geometric mean for that quarter

a. 550,000

b. 2,350,000

c. 1,780,000

d. 2,660,000

6. Lab results on fecal coliform are 450, 650, 215, 238, 685, 65, 985

Calculate the geometric mean of the above series of numbers

a. 65.0

b. 469.7

c. 351.0

d. 985.0

7. Fecal coliform results indicate

1. 92,000,000

2. 106,000,000

3. 152,000,000

4. 152,000,000

Calculate geometric mean

a. 92,000,000

b. 125,500,000

c. 152,000,000

d. 122,000,000

8. Find the anti-log of 2.69461

a. 49.5

b. 495

c. 4950

d. 42975

Module No:	Topic: Evaluation

Instructor Notes:	Instructor Outline:
1. Handout	1. Give 10 evaluation problems.
Answers	
1. a	
2. b	
3. d	
4. a	
5. c	
6. c	
7. d	
8. b	

—Common logarithms of numbers—

N.	L. 0	1	2	3	4	5	6	7	8	9
10	00 000	00 432	00 860	01 284	01 703	02 119	02 531	02 938	03 342	03 743
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14	14 613	14 922	15 229	15 534	15 836	16 137	16 435	16 732	17 026	17 319
15	17 609	17 898	18 184	18 469	18 752	19 033	19 312	19 590	19 866	20 140
16	20 412	20 683	20 952	21 219	21 484	21 748	22 011	22 272	22 531	22 789
17	23 045	23 300	23 553	23 805	24 055	24 304	24 551	24 797	25 042	25 285
18	25 527	25 768	26 007	26 245	26 482	26 717	26 951	27 184	27 416	27 646
19	27 875	28 103	28 330	28 556	28 780	29 003	29 226	29 447	29 667	29 885
20	30 103	30 320	30 535	30 750	30 963	31 175	31 387	31 597	31 806	32 015
21	32 222	32 428	32 634	32 838	33 041	33 244	33 445	33 646	33 846	34 044
22	34 242	34 439	34 635	34 830	35 025	35 218	35 411	35 603	35 793	35 984
23	36 173	36 361	36 549	36 736	36 922	37 107	37 291	37 475	37 658	37 840
24	38 021	38 202	38 382	38 561	38 739	38 917	39 094	39 270	39 445	39 620
25	39 794	39 967	40 140	40 312	40 483	40 654	40 824	40 993	41 162	41 330
26	41 497	41 664	41 830	41 996	42 160	42 325	42 488	42 651	42 813	42 975
27	43 136	43 297	43 457	43 616	43 775	43 933	44 091	44 248	44 404	44 560
28	44 716	44 871	45 025	45 179	45 332	45 484	45 637	45 788	45 939	46 090
29	46 240	46 389	46 538	46 687	46 835	46 982	47 129	47 276	47 422	47 567
30	47 712	47 857	48 001	48 144	48 287	48 430	48 572	48 714	48 855	48 996
31	49 136	49 276	49 415	49 554	49 693	49 831	49 969	50 106	50 243	50 379
32	50 515	50 651	50 786	50 920	51 055	51 188	51 322	51 455	51 587	51 720
33	51 851	51 983	52 114	52 244	52 375	52 504	52 634	52 763	52 892	53 020
34	53 148	53 275	53 403	53 529	53 656	53 782	53 908	54 033	54 158	54 283
35	54 407	54 531	54 654	54 777	54 900	55 023	55 145	55 267	55 388	55 509
36	55 630	55 751	55 871	55 991	56 110	56 229	56 348	56 467	56 585	56 703
37	56 820	56 937	57 054	57 171	57 287	57 403	57 519	57 634	57 749	57 864
38	57 978	58 092	58 206	58 320	58 433	58 546	58 659	58 771	58 883	58 995
39	59 106	59 218	59 329	59 439	59 550	59 660	59 770	59 879	59 988	60 097
40	60 206	60 314	60 423	60 531	60 638	60 746	60 853	60 959	61 066	61 172
41	61 278	61 384	61 490	61 595	61 700	61 805	61 909	62 014	62 118	62 221
42	62 325	62 428	62 531	62 634	62 737	62 839	62 941	63 043	63 144	63 246
43	63 347	63 448	63 548	63 649	63 749	63 849	63 949	64 048	64 147	64 246
44	64 345	64 444	64 542	64 640	64 738	64 836	64 933	65 031	65 128	65 225
45	65 321	65 418	65 514	65 610	65 706	65 801	65 896	65 992	66 087	66 181
46	66 276	66 370	66 464	66 558	66 652	66 745	66 839	66 932	67 025	67 117
47	67 210	67 302	67 394	67 486	67 578	67 669	67 761	67 852	67 943	68 034
48	68 124	68 215	68 305	68 395	68 485	68 574	68 664	68 753	68 842	68 931
49	69 020	69 108	69 197	69 285	69 373	69 461	69 548	69 636	69 723	69 810
50	69 897	69 984	70 070	70 157	70 243	70 329	70 415	70 501	70 586	70 672
N.	L. 0	1	2	3	4	5	6	7	8	9

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War Department July 10, 1940

—Common logarithms of numbers—

N.	L. 0	1	2	3	4	5	6	7	8	9
50	69 897	69 984	70 070	70 157	70 243	70 329	70 415	70 501	70 586	70 672
51	70 757	70 842	70 927	71 012	71 096	71 181	71 265	71 349	71 433	71 517
52	71 600	71 684	71 767	71 850	71 933	72 016	72 099	72 181	72 263	72 346
53	72 428	72 509	72 591	72 673	72 754	72 835	72 916	72 997	73 078	73 159
54	73 239	73 320	73 400	73 480	73 560	73 640	73 719	73 799	73 878	73 957
55	74 036	74 115	74 194	74 273	74 351	74 429	74 507	74 586	74 663	74 741
56	74 819	74 896	74 974	75 051	75 128	75 205	75 282	75 358	75 435	75 511
57	75 587	75 664	75 740	75 815	75 891	75 967	76 042	76 118	76 193	76 268
58	76 343	76 418	76 492	76 567	76 641	76 716	76 790	76 864	76 938	77 012
59	77 085	77 159	77 232	77 305	77 379	77 452	77 525	77 597	77 670	77 743
60	77 815	77 887	77 960	78 032	78 104	78 176	78 247	78 319	78 390	78 462
61	78 533	78 604	78 675	78 746	78 817	78 888	78 958	79 029	79 099	79 169
62	79 239	79 309	79 379	79 449	79 518	79 588	79 657	79 727	79 796	79 865
63	79 934	80 003	80 072	80 140	80 209	80 277	80 346	80 414	80 482	80 550
64	80 618	80 686	80 754	80 821	80 889	80 956	81 023	81 090	81 158	81 224
65	81 291	81 358	81 425	81 491	81 558	81 624	81 690	81 757	81 823	81 889
66	81 954	82 020	82 086	82 151	82 217	82 282	82 347	82 413	82 478	82 543
67	82 607	82 672	82 737	82 802	82 866	82 930	82 995	83 059	83 123	83 187
68	83 251	83 315	83 378	83 442	83 506	83 569	83 632	83 696	83 759	83 822
69	83 885	83 948	84 011	84 073	84 136	84 198	84 261	84 323	84 386	84 448
70	84 510	84 572	84 634	84 696	84 757	84 819	84 880	84 942	85 003	85 065
71	85 126	85 187	85 248	85 309	85 370	85 431	85 491	85 552	85 612	85 673
72	85 733	85 794	85 854	85 914	85 974	86 034	86 094	86 153	86 213	86 273
73	86 332	86 392	86 451	86 510	86 570	86 629	86 688	86 747	86 806	86 864
74	86 923	86 982	87 040	87 099	87 157	87 216	87 274	87 332	87 390	87 448
75	87 506	87 564	87 622	87 679	87 737	87 795	87 852	87 910	87 967	88 024
76	88 081	88 138	88 195	88 252	88 309	88 366	88 423	88 480	88 536	88 593
77	88 649	88 705	88 762	88 818	88 874	88 930	88 986	89 042	89 098	89 154
78	89 209	89 265	89 321	89 376	89 432	89 487	89 542	89 597	89 653	89 708
79	89 763	89 818	89 873	89 927	89 982	90 037	90 091	90 146	90 200	90 255
80	90 309	90 363	90 417	90 472	90 526	90 580	90 634	90 687	90 741	90 795
81	90 849	90 902	90 956	91 009	91 062	91 116	91 169	91 222	91 275	91 328
82	91 381	91 434	91 487	91 540	91 593	91 645	91 698	91 751	91 803	91 855
83	91 908	91 960	92 012	92 065	92 117	92 169	92 221	92 273	92 324	92 376
84	92 428	92 480	92 531	92 583	92 634	92 686	92 737	92 788	92 840	92 891
85	92 942	92 993	93 044	93 095	93 146	93 197	93 247	93 298	93 349	93 399
86	93 450	93 500	93 551	93 601	93 651	93 702	93 752	93 802	93 852	93 902
87	93 952	94 002	94 052	94 101	94 151	94 201	94 250	94 300	94 349	94 399
88	94 448	94 498	94 547	94 596	94 645	94 694	94 743	94 792	94 841	94 890
89	94 939	94 988	95 036	95 085	95 134	95 182	95 231	95 279	95 328	95 376
90	95 424	95 472	95 521	95 569	95 617	95 665	95 713	95 761	95 809	95 856
91	95 904	95 952	95 999	96 047	96 095	96 142	96 190	96 237	96 284	96 332
92	96 379	96 426	96 473	96 520	96 567	96 614	96 661	96 708	96 755	96 802
93	96 848	96 895	96 942	96 988	97 035	97 081	97 128	97 174	97 220	97 267
94	97 313	97 359	97 405	97 451	97 497	97 543	97 589	97 635	97 681	97 727
95	97 772	97 818	97 864	97 909	97 955	98 000	98 046	98 091	98 137	98 182
96	98 227	98 272	98 318	98 363	98 408	98 453	98 498	98 543	98 588	98 632
97	98 677	98 722	98 767	98 811	98 856	98 900	98 945	98 989	99 034	99 078
98	99 123	99 167	99 211	99 255	99 300	99 344	99 388	99 432	99 476	99 520
99	99 564	99 607	99 651	99 695	99 739	99 782	99 826	99 870	99 913	99 957
100	00 000	00 043	00 087	00 130	00 173	00 217	00 260	00 303	00 346	00 389
N.	L. 0	1	2	3	4	5	6	7	8	9

Module No:	Module Title: Advanced Mathematics
	Submodule Title: Total Head
Approx. Time: 1 hour	Topic: Conversion

Objectives:

The learner will demonstrate the ability to convert:

1. The height of a water column from feet to pounds per square inch (psi).
2. Convert pounds per square inch (psi) to feet.

Instructional Aids:

Handout
AV (overhead transparency)

Instructional Approach:

Discussion
Demonstration
Exercise

References:

Manual of Water Utility Operations, Texas Water Utilities Association.

Mathematics for Water and Wastewater Treatment Plant Operators, Kirkpatrick, Ann Arbor Science.

Class Assignments:

Given 10 exercise problems to be solved.

Module No:	Topic: Conversion

Instructor Notes:	Instructor Outline:

1. Discuss/demonstrate how one converts feet to PSI by using the formula:

   PSI = feet x 0.433

   PSI = Pounds/square inch

   Feet - Height of water column

2. Discuss/demonstrate how one converts PSI to feet by using the formula:

   a. $\text{Feet} = \frac{\text{PSI}}{0.433}$

      Feet = Height of water column

      PSI = Pounds/square inch

   b. Feet = PSI x 2.31

      Feet = Height of water column

      PSI = Pounds/square inch

TOTAL HEAD

A. Pressure

Force and pressure are sometimes used interchangeably. The definition of FORCE is the weight of the liquid while PRESSURE is the force applied to a unit area. Since liquids are acted upon by the gravitational pull (force) then it also can exert a pressure.

From the definition of pressure the formula is

$$P = \frac{W}{A}$$

P = Pressure/lbs/in^2

W = Height - lbs.

A = Area - in^2

Example

A weight of 3,000 lbs. is placed on a surface area of 300 square inches. Calculate the pressure exerted by the weight.

Solution

$$P = \frac{W}{A}$$

$$= \frac{3{,}000 \text{ lbs.}}{300 \text{ in}^2}$$

$$= 10 \text{ lbs/in}^2$$

Pressure exerted by a liquid column.

A container having inside dimensions of one inch by one inch by one foot depth exactly will hold .433 lbs. of water.

This can provide the ratio that water with a depth or height of one foot will exert a pressure of .433 lbs/in^2 If the column of water was more than one foot high, then the formula to use is

$$P = H \times 0.433$$

P = Pressure in lbs/in^2

H = Height in feet

Example

A water tower is 100 feet high. Calculate the pressure exerted by the water.

$P = H \times 0.433$

$= 100 \times 0.433$

$= 43.3\ \text{lbs/in}^2$

By revising the formula to

$P = H \times 0.433$

$H = \dfrac{P}{0.433}$

If the pressure exerted is 1 lbs/in^2

Then $H = \dfrac{P}{0.433}$

$= \dfrac{1}{0.433}$

$= 2.31$ ft.

This means that to exert 1 lb/in^2 of pressure a column of water has a height or depth of 2.31 feet.

To convert pressure to height use the formula

a. $H = \dfrac{PSI}{0.433}$

or

b. $H = PSI \times 2.31$

Example

A gauge at the bottom of a tank reads 16 PSI (G). Calculate the depth of water in the tank.

Solution

$H = PSI \times 2.31$

$= 16 \times 2.31$

$= 36.96$ ft.

In the field of water and wastewater technology the greatest area of use of pressure is when there is movement of liquids from one point to another. To accomplish this movement one must take into account the

a. Height the liquid is moved to

b. The pressure exerted by the weight of the liquid

c. The velocity the liquid is moving at

d. The "head" losses due to

1. Friction of pipe and liquid

2. Change in sizes of pipe

3. Bends, valves and other pipe appertenances

By combining all the factors that the movement of liquid has to overcome, the term TOTAL DYNAMIC HEAD or TOTAL HEAD is determined. Total dynamic head (TDH) is reported in feet. TDH is the amount of pressure that has to be overcome to be able to cause movement of liquid from one point to another.

Exercise

The gauge at the discharge line of a pump indicates a reading of 125 PSI. What is the discharge head?

Solution

H = Pressure x 2.31

= 125 x 2.31

= 288.75 feet

Exercise

1. What is the pressure at the bottom of a tank with an area of 185 square inches that contains 16,650 lbs. of water.

2. A water column with a radius of 10 ft. is filled with water. The pressure indicator shows 100 PSI. Calculate the height of the water column.

3. What is the pressure applied on the bottom of a rectangular tank 10 ft. length, 5 ft. width and 4 ft. deep.

4. A water line in a tower is 125 ft. high. Calculate the pressure exerted by the water at the base of the tower.

5. The discharge gauge on a pump indicates 23 PSI. Calculate the head against the pump.

6. What is the gauge pressure under 5 ft. of water.

7. Calculate the head equivalent to 60 PSI.

8. A water tower 110 ft. contains 1.8 MG. Calculate the pressure exerted by the weight of the water.

9. If the pressure in a water main is 70 PSI, calculate the minimum loss in water pressure to a faucet 28 ft. above the main.

10. If the pressure in a water main is 65 PSI, calculate the maximum pressure that could occur at a faucet 50 ft. above the main (only static head is being sought).

Module No:	Module Title: Advanced Mathematics
	Submodule Title: Steady Flow in a Pipe
Approx. Time: 1 hour	Topic: Steady Flow

Objectives:

The learner will demonstrate the ability to calculate the steady flow of water through:

1. A single size (diameter) pipe.
2. Different sizes (diameter) pipe, connected.

Instructional Aids:

Handouts
AV (overhead transparency)

Instructional Approach:

Discussion
Demonstration
Exercise

References:

Manual of Water Utility Operations, Texas Water Utilities Association.

Mathematics for Water and Wastewater Treatment Plant Operators, Kirkpatrick, Ann Arbor Science.

Class Assignments:

Give 8 exercise problems to be solved.

Module No:	Topic: Steady Flow

Instructor Notes:	Instructor Outline:
1. Give handout	1. Discuss/demonstrate how one calculates the steady flow in a single sized pipe using the formula:
Q is in cubic fee/sec.	$Q = AV$
A is in square feet	Q = The flow rate
V is in feet/sec.	A = Cross sectional area of the pipe
	V = Velocity of the water moving through the pipe
	2. Discuss/demonstrate how one calculates the steady flow in different size pipe connected to each other using the formula:
	$Q_1 = A_1 V_1$.
	and
	$Q_2 = A_2 V_1$
	Since $Q_1 = Q_2$
	Then
	$A_1 V_1 = A_2 V_1$
Q_1 is in cubic/sec.	Q_1 = Flow rate in pipe (1)
Q_2	Q_2 = Flow rate in pipe (2)
A_1 is in square feet	A_1 = Cross sectional area of pipe (1)
V_1 is in feet/sec.	V_1 = Velocity of water through pipe (1)
A_2 is in square feet	A_2 = Cross section of area of pipe (2)
V_2 is in feet/sec.	V_2 = Velocity of water through pipe (2)
Refer to Module No.	
Submodule Title Volumes Topic cylinders.	
	3. Give 8 exercise problems

STEADY FLOW IN A PIPE

The flow rate of a liquid can be determined using the formula

Q = AV

Q = Flow rate

A = Wetted cross sectional area of the pipe

V = The velocity of the liquid

NOTE: IF THE PIPE IS FULL FLOW THAN IT IS SIMPLE TO DETERMINE THE WETTED CROSS SECTIONAL AREA. BUT IF THE PIPE IS PARTIALLY FULL TO CALCULATE THE WETTED CROSS SECTIONAL AREA IS BEYOND THE SCOPE OF THIS MODULE ESPECIALLY IF THE PIPE IS CIRCULAR.

Example

Calculate the flow rate in a 12 inch main if the velocity is 4 feet per sec.

Solution

Q = AV

a. $A = .785 \times D^2$

$= .785 \times 12 \times 12$

= 113.04 square inches

b. Convert 113.04 sq. in. to sq. ft.

$= \frac{113.04}{114}$

= .785 sq. ft.

c. Q = AV

$= .785\ ft^2 \times 4\ ft./sec.$

$= 3.14\ ft^3/sec.$

d. If Q is required in gallons then convert ft^3/sec. to GPS

$= 3.14 \times 7.48$

= 23.5 GPS

In a piping system there may very well be different sizes of pipe.

Example

An 8" main is connected to a 6" main. This will evoke the continuity principle.

The continuity principle states that a volume of liquid entering the pipe at one end per unit time, must leave the other end in the same unit time. If this principle did not apply then if less liquid leaves the pipe than enters it, the volume will build up so will the pressure (liquids are non-compressable) and the pipe may break, or if more liquid leaves the pipe than enters it, the pipe will eventually empty.

Assuming that a series of pipes are connected then from the continuity principle:

$Q_1 = Q_2 = Q_3 = Q_4$

Where (Q) is the flow rate from each pipe.

Substituting for Q

$Q_1 = A_1 V_1$

$Q_2 = A_2 V_2$

$Q_3 = A_3 V_3$

$Q_4 = A_4 V_4$

Therefore

$A_1 V_1 = A_2 V_2 = A_3 V_3 = A_4 V_4$

Since the cross sectional area is changed then the velocity has to change.

Example

Two pipes one 4 inches in diameter, the second 6 inches in diameter are connected. The flow is from the 4 inch to the 6 inch pipe and the velocity is 8 ft/sec. in the 4 inch pipe. Calculate the velocity through the 6 inch pipe.

Solution

$A_1 V_1 = A_2 V_2$

Since V_2 is the unknown then

$V_2 = \frac{A_1 V_1}{A_2}$

$$V_2 = \frac{.785 \times D_1^2 \times V_1}{.785 \times D_2^2}$$

The .785 cancels out

Then

$$V_2 = \frac{4 \text{ in.} \times 4 \text{ in.} \times 8 \text{ ft/sec.}}{6 \text{ in.} \times 6 \text{ in.}}$$

V_2 = 3.5 ft/sec.

Exercise

1. A 12" main flowing full with a velocity of 6 ft/sec., what is the volume of water delivered in 10 hrs.

2. An 8" sewer line flowing full with a velocity of 2 ft/sec. Calculate the rate of flow.

3. A 6" sewer line flowing half full with a velocity of 2.3 ft/sec., calculate the rate of flow.

4. Two connected water mains, the input line is 6 inches and the output line is 8 inches. The velocity of the liquid in the input line is 10 ft/sec.

   a. Calculate the rate of flow through the system.

   b. Calculate the velocity at the output end.

5. A horizontal section of pipe has two diameters. The first is 8 inches and the second 12 inches. If the flow rate is 80 ft^3/sec. calculate

   a. Velocity in the 8" diameter pipe.

   b. Velocity in the 12" diameter pipe

6. An 18" main flowing full with a velocity of 8 ft/sec, is connected to two 8" mains. Each 8" main receives equal volume of flow. Calculate the velocity in the 8" main.

7. A pressure sewer line 6" in diameter delivers a volume of 380,000 gallons per day. Calculate the velocity.

8. Calculate the average velocity in a grit chamber 12 ft. long x 2 ft. wide x 18" water depth if the flow rate is 1.9 MGD.

Module No:	Module Title: .Advanced Mathematics
	Submodule Title: Flow Measurement
Approx. Time: 3 hours	Topic: Flow Measurement

Objectives:

The learner will demonstrate the ability to calculate the flow of water using the equation of:

1. A venturi meter
2. A suppressed rectangular weir
3. A v-notch (90^{o}) weir

Instructional Aids:

Handout
AV (overhead transparency)

Instructional Approach:

Discussion
Demonstration
Exercise

References:

Manual of Water Utility Operations, Texas Water Utilities Association.

Mathematics for Water and Wastewater Treatment Plant Operators, Kirkpatrick, Ann Arbor Science.

Class Assignments:

Given 10 exercise problems to be solved.

Module No:	Topic: Flow Measurement

Instructor Notes:	Instructor Outline:
Handout	1. Discuss/demonstrate how one calculates the flow of water using the formula of a venturi meter.
	$Q = \frac{A_1 \times A_2}{\sqrt{(A_1)^2 - (A_2)^2}} \times \sqrt{\frac{2g}{W} \times (P_1 - P_2)}$
	Q = Flow rate
	A_1 = The cross sectional area of the discharge end of the meter
	A_2 = The cross sectional area of the throat of the meter
	g = The gravitational pull of 32 ft./sec.^{2}
P_1 is in PSI	P_1 = The pressure gauge reading on the the discharge end of the meter
P_2 is in PSI	P_2 = The pressure gauge reading on the throat of the meter.
W of water is 62.4 lbs/ft^3	W = Specific weight of the liquid being pumped
Refer to Module No. ____ Submodule Title areas Topic circle	
Refer to Module No. ____ Submodule Title Statistics Topic Geometric Mean	2. Discuss/demonstrate how one calculates the flow of water using the formula of a suppressed rectangular weir neglecting velocity.
	$Q = 3.33\ L \times H^{3/2}$
Q is in cubic feet/sec.	Q = Flow rate
L is in feet	L = Length of weir crest
H is in feet	H = Head on weir crest

Module No:	Topic: Flow Measurement

Instructor Notes:	Instructor Outline:
	3. Discuss/demonstrate how one calculates the flow of water using the formula of a 90° V notch weir neglecting velocity.
	$Q = 2.49 \times H^{2.48}$
Q is in cubic feet/sec.	Q = Flow rate
H is in feet	H = Head on weir crest
	4. Discuss/demonstrate the use of nanograms

VENTURI METER

The venturi meter operates on the idea of the continuity principle which says that changing the pipe size will change the velocity. When the velocity changes so does the pressure exerted by the liquid. The ratio and proportion is reducing the cross area of the pipe increases the velocity and reduces the pressure.

The formula to use in determining the flow rate (Q) using a venturi meter is

$$Q = \frac{A_1 \times A_2}{\sqrt{(A_1)^2 - (A_2)^2}} \times \sqrt{\frac{2g}{W} \times (P_1 - P_2)}$$

Q = Flow rate in $ft^3/sec.$

A_1 = Area of large diameter pipe

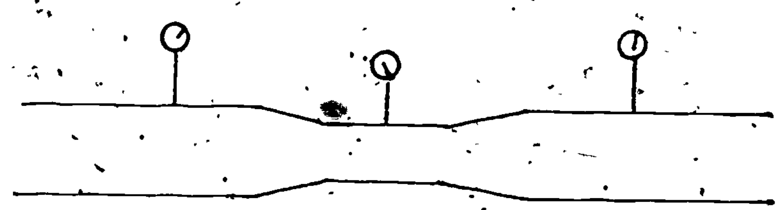
A_2 = Area of small diameter pipe (throat)

g = The gravitational pull 32 $ft./sec.^2$

W = The specific weight of the liquid (water is 62.4 $lbs/ft.^3$)

P_1 = The pressure at large diameter pipe in PSI

P_2 = The pressure at small diameter pipe in PSI



Example

A venturi meter has an input diameter of 6 inches and a throat of 31 inches. The input pressure (P_1) is 9 PSI and the throat pressure (P_2) is 5 PSI. Calculate the rate of flow.

Solution

To be able to use the formula

$$Q = \frac{A_1 \times A_2}{\sqrt{(A_1)^2 - (A_2)^2}} \times \sqrt{\frac{2g}{W}(P_1 - P_2)}$$

First determine A_1

Second determine A_2

$A_1 = .785 \times D^2$

$= .785 \times (6)^2$

$= 28.26$ sq. inches

$= \frac{28.26}{144} = 0.196$ sq. ft.

$A_2 = .785 \times D^2$

$= .785 \times (3)^2$

$= 7.065$ sq. inches

$= \frac{7.065}{144} = 0.049$ sq. ft.

$$\frac{A_1 \times A_2}{\sqrt{(A_1)^2 - (A_2)^2}}$$

$$= \frac{0.196 \text{ ft.}^2 \; .049 \text{ ft.}^2}{\sqrt{(0.196 \text{ ft.}^2) - (.049 \text{ ft.}^2)^2}}$$

$$= \frac{.01 \text{ ft.}^4}{.189 \text{ ft.}^2}$$

$$= .05 \text{ ft.}^2$$

$$= \sqrt{\frac{2g}{W}(P_1 - P_2)}$$

$$= \sqrt{\frac{2 \times 32 \text{ ft/sec.}^2}{64 \text{ lbs/ft.}^3} (9 - 5) \text{ lbs/in}^2}$$

$$= \sqrt{\frac{4.184 \text{ ft}^2}{\text{Sec.}^2 \times \text{in}^2}}$$

$= \frac{2.05 \text{ ft}^2}{\text{Sec. x in.}}$

Since 1 ft. = 12 in.

Therefore

$\frac{2.05 \text{ ft. x } 12 \text{ in.}}{\text{Sec. x in.}}$

= 24.6 ft./sec.

$$Q = \frac{A_1 \times A_2}{\sqrt{(A_1)^2 - (A_2)^2}} \times \sqrt{\frac{2g}{W}(P_1 - P_2)}$$

= 0.05 ft.^{2} x 24.6 ft/sec.

= 1.23 ft^3/sec.

NOTE: Since A_1, A_2, g & W are constant for that particular venturi meter unit, one can obtain a constant (k) and when the pressures change use the formula

$Q = k\sqrt{P_1 - P_2}$

Example

Using the problem from the previous example (large diameter 6 inches, throat 3 inches, P_1 - 9 PSI, P_2 - 5 PSI) determine the rate of flow when

a. P_1 = 11 PSI

P_2 = 5 PSI

b. P_1 = 8

P_2 = 3

Solution

$$Q = \frac{A_1 \times A_2}{\sqrt{(A_1)^2 - (A_2)^2}} \times \sqrt{\frac{2g}{W}(P_1 - P_2)}$$

or $Q = k\sqrt{P_1 - P_2}$

$$k = \frac{A_1 \times A_2}{\sqrt{(A_1)^2 - (A_2)^2}} \times \sqrt{\frac{2g}{W}}$$

$$= \frac{.196\ ft^2 \times .049\ ft^2}{\sqrt{(.196\ ft^2)^2 - (.049\ ft^2)^2}} \times \sqrt{\frac{64\ ft/sec.^2}{62.4\ lbs/ft^3}}$$

$k = .036\ ft^3/sec.$

Now

1. $P_1 = 11$

   $P_2 = 5$

   $Q = k \times \sqrt{P_1 - P_2}$

   $= .036\ ft^3/sec.\ \sqrt{11 - 5}$

   $= .036\ ft^3/sec. \times 2.45$

   $= 1.56\ ft^3/sec.$

2. $P_1 = 8$

   $P_2 = 3$

   $Q = k \times \sqrt{P_1 - P_2}$

   $= .036 \times \sqrt{8 - 3}$

   $= 1.43\ ft^3/sec.$

Exercise

1. A venturi meter is inserted into a horizontal section of water line whose entrance is 18 inches. Find the flow rate of water if the throat diameter is 12 inches. The difference in pressures is 30 PSI.

2. In Problem No. 1, if the pressure difference in PSI at

   8:00 a.m. = 15

   10:00 a.m. = 25

   11:00 a.m. = 20

   12:00 noon = 22

   Calculate the flow rates at the different hours

WEIRS

The shapes and types of weirs are numerous. The most typical ones are

a. Rectangular weirs with no end contractions. The formula is

$$Q = 33\ L \times H^{3/2}$$

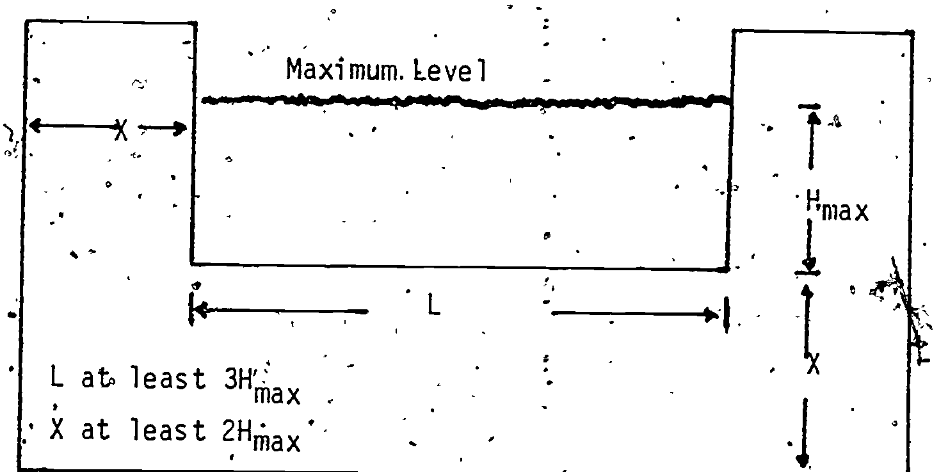
Q = Flow rate in CFS

L = Effective width of the weir in ft.

H = Head in ft.

b. Rectangular weirs with end contractions. The formula is

$$Q = 3.33 \times L \times H^{3/2} - 0.66\ H^{5/2}$$



RECTANGULAR WEIR

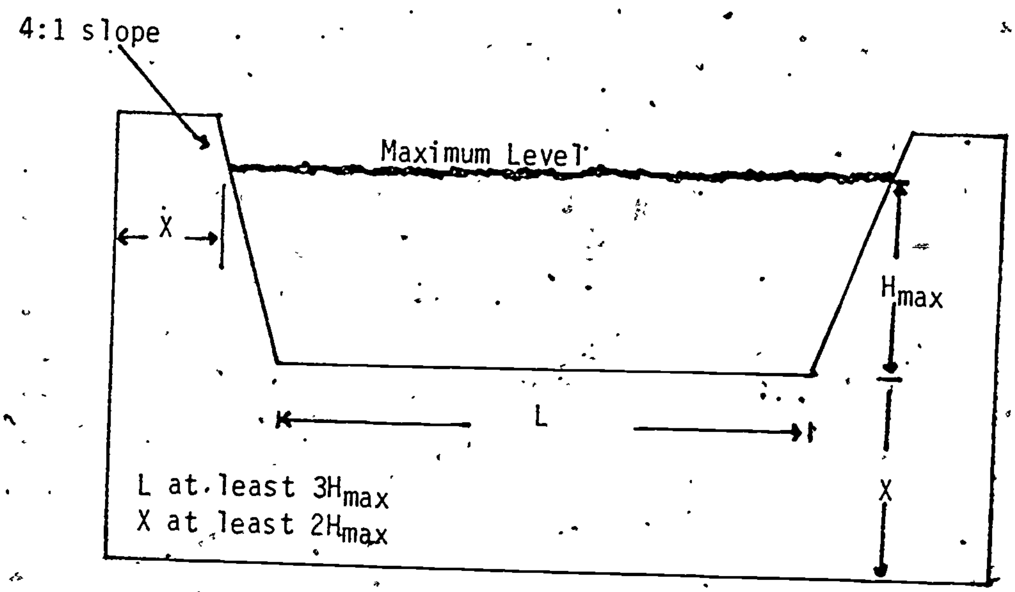
c. Cipolletti weir. The formula is

$Q = 3.367 \times L \times H^{3/2}$

Q = Flow rate in CFS

L = Length of the weir opening at the base in ft.

H = Measured head in ft.



CIPOLLETTI WEIR

d. Triangular weirs

The most commonly used angle for the v-notch weirs being 90° and 60°. The formula to use with a 90° v-notch weir with no end contraction is

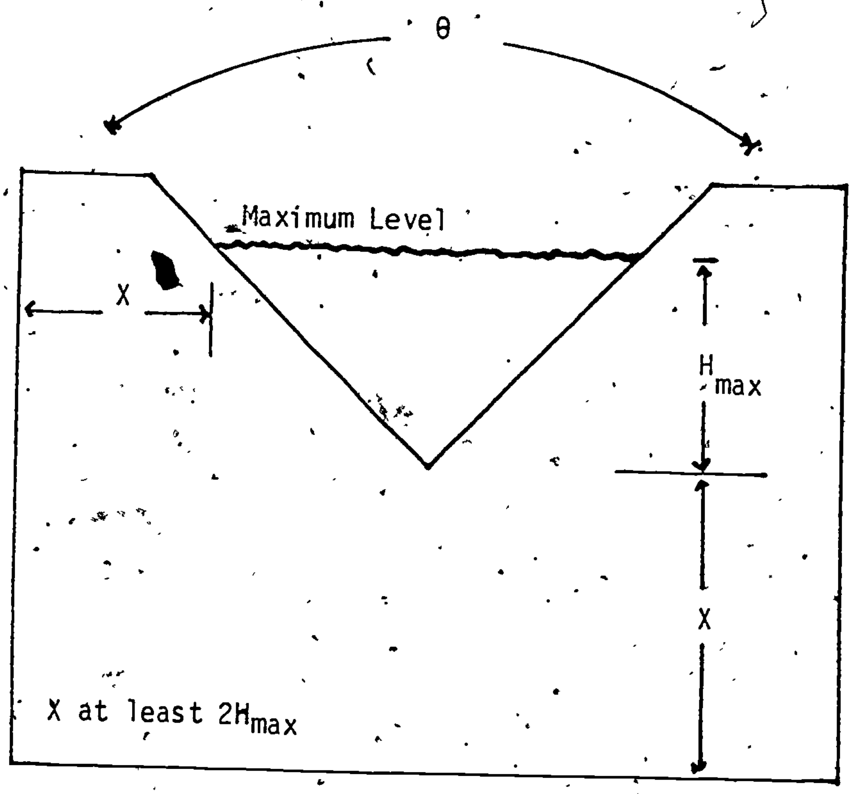
$Q = 2.49 \times H^{5/2}$

Q = Flow rate in CFS

H = Head in ft.

e. 90° v-notch weir with end contraction. The formula is

$Q = 2.4381 \times H^{5/2}$



TRAINGULAR
or
V-NOTCH WEIR

In calculating for flow rates (Q) using any of the formulas given, the use of logarithm tables is extremely helpful in determining the value for $H^{3/2}$. This is accomplished by

a. Finding the logarithm of H

b. Multiplying by 3 or 5 depending on the formula

c. Dividing by 2

d. Find the anti-log of the result, remember that H has to be in ft.

Example

Calculate the flow-rate using a cipolleti weir. If the length of opening at the base is 3 ft. and the water height (head) over the weir is 4 inches.

Solution

$Q = 3.367 \times L \times H^{3/2}$

First determine $H^{3/2}$.

a. Log of H = 0.60206

b. Log of H x 3 = 1.80618

c. Log of H x 3 ÷ 2 = .90309

d. Anti-log of .90309 = 8 inches

e. Change inches to ft = 8 ÷ 12 = 0.67 ft.

Therefore

Q = 3.367 x 3 x .67 ft.

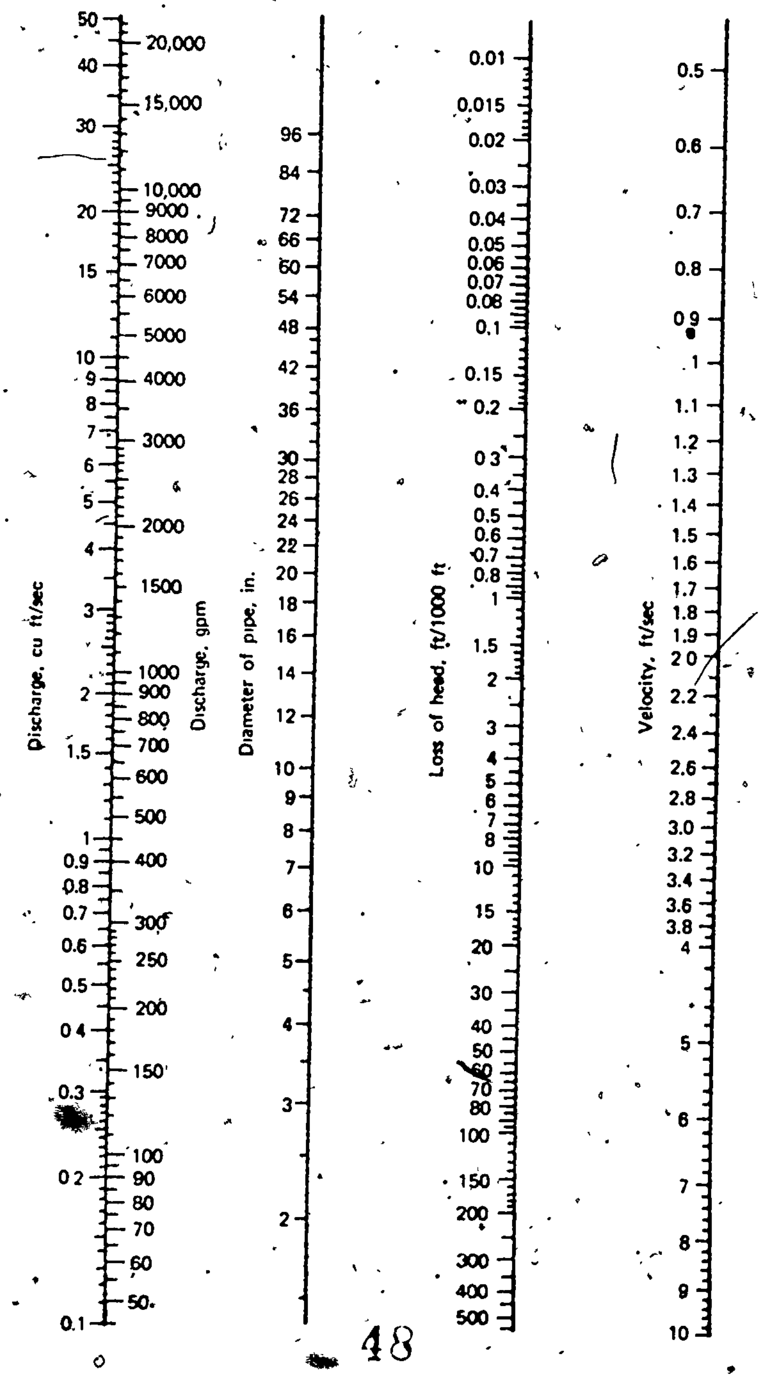
= 6.77 CFS

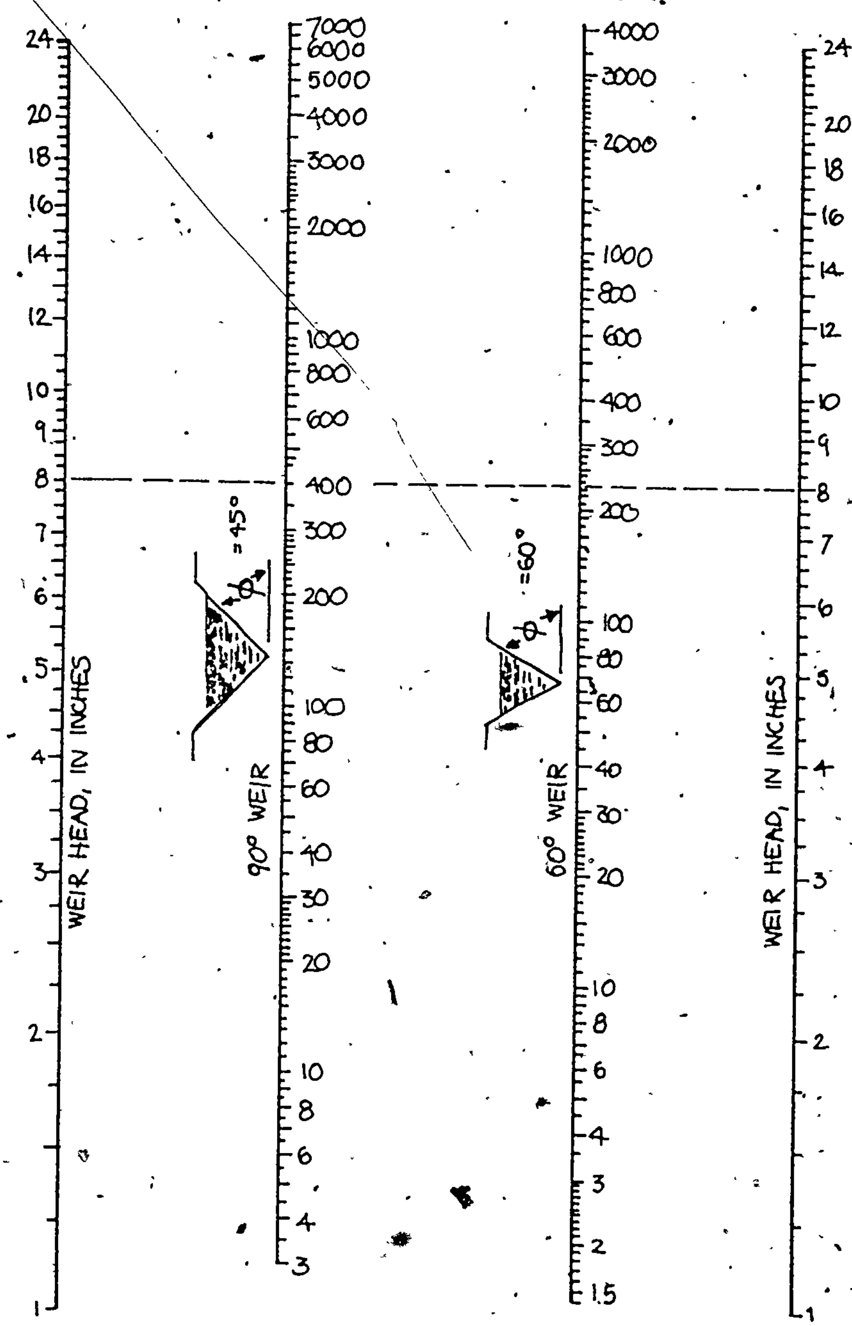
NANOGRAMS

Nanograms are graphs designed to simplify determination of values.

A three column nanogram is used by joining with a line two known values, the third value is at the intersection of the column and the line.

Two column nanograms are used by drawing a perpendicular line from the column of the unknown value to the column of the unknown value. The intersection is the sought value.





Flow Rates For 60° and 90° V-Notch Weirs (3)

Exercise

1. Calculate the flow rate using a 90° v-notch weir with contracted ends if the level of water over the weir is

   a. 3.8 inches

   b. 5.2 inches

   c. 1.5 inches

2. Using a nanogram determine the flow rate for a 60° v-notch weir if the head is

   a. 7 inches

   b. 1.5 inches

   c. 1 foot

3. Determine the flow rate in a channel using a cipolleti weir. Given:

   a. 2.7 inches head, 2 ft. length of weir opening at base.

   b. 1.5 feet head, 3 ft. length of weir opening at base.

   c. 21 inches head, 4 ft. length of weir opening at base.

Module No:	Module Title: Advanced Mathematics
	Submodule Title: Pump and Motor Power and Efficiency
Approx. Time: 3 hours	Topic: Pump and Motor Power and Efficiency

Objectives:

The learner will demonstrate the ability to:

1. Identify the data obtained from a given pump curve.
2. Calculate the work horsepower (WHP) of a pump needed to deliver a volume of water.
3. Calculate the brake horsepower (bhp) of a pump needed to deliver a volume of water.
4. Calculate motor power input needed to deliver a volume of water using a specified pump.

5. Cost of pumping a volume of water.

Instructional Aids:

Handout
AV (overhead transparency)

Instructional Approach:

Discussion
Demonstration
Exercise

References:

Manual of Water Utility Operations, Texas Water Utilities Association.

Mathematics for Water and Wastewater Treatment Plant Operators, Kirkpatrick, Ann Arbor Science.

Class Assignments:

Given 10 exercise problems to be solved.

Module No:	Topic: Power Efficiency

Instructor Notes:	Instructor Outline:
	1. Discuss/demonstrate how one can obtain specific data such as: a. TDH = Total head b. GPM = Gallons per minute c. BHP = Brake horsepower d. Efficiency
	2. Discuss/demonstrate how one calculates the work horsepower (WHP) of a pump using the formula: $WHP = \frac{Q \times TDH \times Sp. Gr.}{3960}$ WHP = Work horsepower Q = Flow rate in GPM TDH = Total head against pump Sp. Gr. = Specific gravity of liquid being pumped.
	3. Discuss/demonstrate how one calculates the brake horsepower (bhp) of a pump using the formula: a. $bhp = \frac{Q \times TDH \times Sp. Gr.}{3960\ Pe}$ bhp = Brake horsepower Q = Flow rate in GPM TDH - Total head against pump Sp. Gr. = Specific gravity of liquid being pumped.
Pe is in decimal %	Pe = Pump efficiency

Module No:	Topic: Power Efficiency

Instructor Notes:	Instructor Outline:
	b. $bhp = \frac{whp}{Pe}$
	bhp = Brake horsepower
	wph = Work horsepower
	Pe = Pump efficiency
	4. Discuss/demonstrate how one calculates the motor (power) input using the formula:
	a. $MPi = \frac{Q \times TDH \times Sp.\ Gr.}{3960 \times Pe \times Me}$
	Mpi = Motor power input
	Q = Flow rate in GPM
	TDH - Total head against pump
	Sp. Gr. = Specific gravity of liquid being pumped
Pe is in decimal %	Pe = Pump efficiency
Me is in decimal %	Me = Motor efficiency
	b. $Mpi = \frac{bhp}{Me}$
	Mpi = Motor power input
	bhp = Brake horsepower
Me is in decimal %	Me = Motor efficiency

Module No:	Topic: Power Efficiency

Instructor Notes:	Instructor Outline:
	5. Discuss/demonstrate how one calculates the cost of pumping using the formula:
	a. bwh/1000 gal. = $\frac{\text{TDH x 0.00314}}{\text{Pe x Me}}$
	bwh/1000 gal. = Kilowatts per 1000 gallons of water pumped
TDH is in ft.	TDH = Total head
Pe is in decimal %	Pe = Pump efficiency
Me is in	Me = Motor efficiency
	b. kwh = 1000 gal. =
	$\frac{\text{Kw Input to motor x 16.7}}{\text{Q}}$
	bwh/1000 gal. = Kilowatts per 1000 gallons of water pumped
	kw input to motor = power in Kilowatts that the motor draws
	Q = Flow rate or GPM

Pumps and Motor

What makes water be transferred from one point to another is usually a pump driven by a motor.

The size of pump and motor depend on

a. The volume of water needed
b. The total head

Most manufacturers provide a pump curve.

Usual information obtained from pump curves are

a. Total head
b. Volume in GPM
c. Efficiency of the pump under the head and GPM load.
d. Brake horsepower

Use of Pump Curve

By knowing the total head the pump has to work against, draw a horizontal line to meet the curve. At the intersection of line and curve draw a perpendicular line to meet the (x) axis or the GPM axis. Read the GPM. It is important to remember that pumps operate best at their peak efficiency about 80 - 85% even though they may not be pumping the maximum GPM.

Refer to Figure 1

Example

If the total head is 60 ft. determine the GPM from Curve 1.

Solution

Ans. 1210 GPM

Exercise

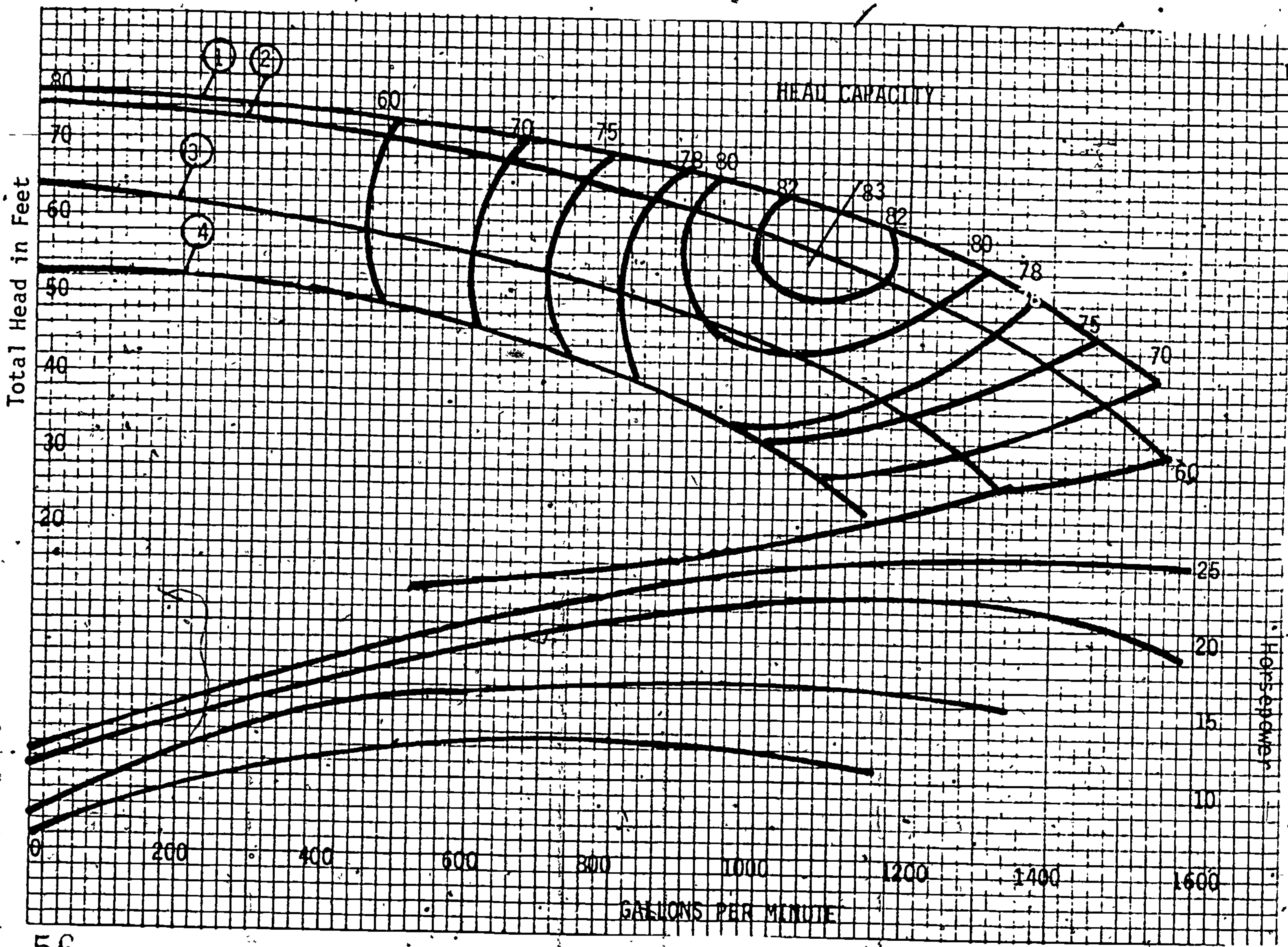
Using Figure I determine -

a. GPM from ourve 1 if total head is 64 ft.

b. Range of GPM from curve 1 at 80% efficiency

c. Range of total head from curve 1 at 80% efficiency

Figure 1


HEAD CAPACITY
Total Head in Feet
80
70
60
50
40
30
20
0
200
400
600
800
1000
1200
1400
1600
GALLONS PER MINUTE
Horsepower
25
20
15
10
1
2
3
4
60
70
75
78
80
82
83
82
80
78
75
70
60

Work Horsepower (WHP)

Work horsepower (WHP) is the power output of a pump to determine the work horsepower (WHP) of a pump. The formula to use is

$$WHP = \frac{Q \times TH \times Sp.\ Gr.}{3960}$$

WHP = Work horsepower

Q = Flow rate in gallons per minute

TH = Total head

3960 = A constant obtained from dividing 33,000 ft.-pounds by 8.34 pounds/gallon

Sp. Gr. = Specific gravity. For water Sp. Gr. is 1 - Sp. Gr. of wastewater ranges from 1.01 to 1.08.

Brake Horsepower (BHP)

Brake horsepower (BHP) is the input power to the shaft of the pump. The formula to use is

A. $$BHP = \frac{Q \times TH \times Sp.\ Gr.}{3960 \times Pe}$$

BHP = Brake horsepower

Q = Flow rate = gallons per minute

TH = Total head

3960 = A constant obtained by dividing 3300 ft.-pounds by 8.34 pounds/gallon

Sp. Gr. = Specific gravity. For water Sp. Gr. is 1 - Sp. Gr. of wastewater ranges from 1.01 to 1.08

Pe = Pump efficiency

B. $$BHP = \frac{WHP}{Pe}$$

BHP = Brake horsepower

WHP = Work horsepower

Pe = Pump efficiency

Motor Power Input (MPI)

Motor Power Input (MPI), also the motor brake horsepower, is the input power to a motor. The formula to use is

A. $MPI = \frac{Q \times TH \times Sp.\ Gr.}{3960 \times Pe \times Me}$

MPI = Motor power input

Q = Flow rate in gallons per minute

TH = Total Head

Sp. Gr. = Specific gravity. For water Sp. Gr. is 1 - Sp. Gr. of wastewater ranges from 1.01 to 1.08

3960 = A constant obtained by dividing 3300 ft.-pounds by 8.34 pounds/gallon

Pe = Pump efficiency

Me = Motor efficiency

B. $MPI = \frac{BHP}{Me}$

MPI = Motor power input

BHP = Brake horsepower

Me = Motor efficiency

COST OF PUMPING A VOLUME OF WATER

The operating cost of pumping water is due to the cost of electricity which is needed to operate the motor.

The formula to use to change horsepower to kilowatts/hour is

kwh = MPI x 0.746

kwh = kilowatts/hour - power consumed

MPI = Motor power input - horsepower

0.746 = A constant where 1 hp. = 0.746 Kw.

The formula to use to determine the cost of pumping is

$$\text{kwh/1000 gallons} = \frac{\text{kw input to motor} \times 1000}{\text{GPM} \times 60}$$

Cost per/1000 gallons = kwh/1000 x cost/kwh

Example

A pump operating against a TH of 93 ft. at a rate of 382 GPM with a pump efficiency of 80% and motor efficiency of 93%. Cost per kwh is 5 cents/kwh. Calculate

1. The WHP of the pump
2. The BHP of the pump
3. The MPI of the motor
4. Cost of pumping/1000 gallons

Solution

1. $$\text{WHP} = \frac{Q \times TH \times \text{Sp. Gr.}}{3960}$$

$$= \frac{382 \times 93 \times 1}{3960}$$

$$= 8.97 \text{ hp}$$

2. $$\text{BHP} = \frac{Q \times TH \times \text{Sp. Gr.}}{3960 \times Pe}$$

$$= \frac{382 \times 93 \times 1}{3960 \times .8}$$

$$= 11.2 \text{ hp}$$

3. $$\text{MPI} = \frac{Q \times TH \times \text{Sp. Gr.}}{3960 \times Pe \times Me}$$

$$\text{or} = \frac{\text{BHP}}{Me}$$

$$= \frac{11.2}{.93}$$

$$= 12$$

4. $kwh = MPI \times 0.746$

$= 12 \times .746$

$= 8.95$ kw input to motor

1 Hp = 746 watts

1 Hp = .746 kilowatts

$$kwh/1000 \text{ gallons} = \frac{bwh \times 1000}{GPM \times 60}$$

$$= \frac{8.95 \times 1000}{382 \times 60}$$

$= 0.39$ kwh/1000 gallons

$cost/1000 = kwh/1000 \times cost/kwh$

$= 0.39 \times 5$

$= 1.95$ cents

Exercise

1. A pump operating against a total head of 115 ft. at a rate of 400 GPM. Pump efficiency is 82%, motor efficiency is 91%. Cost per kwh is 4.85 cents/kwh. Calculate the cost of operating the pump for 18.5 hours per day.

2. Using the pump curve for impeller No. 3; figure (1) determine:

   a. Total head (range)

   b. Gallons/minute (range)

3. Calculate the horsepower (Whp) of a pump needed to deliver 650 GPM if the discharge pressure gauge reads 60 psi.

4. Calculate the cost/1000 gallons given

   a. Total head = 180 ft.

   b. Pump efficiency = 62%

   c. Motor efficiency = 94%

   d. Flow rate = 265 GPM

   e. kwh/cost = 5.2 cents

5. A 10 horse pump pumps at 510 GPM against a total head of 36 psi. If the motor is 93% efficient, calculate the pump efficiency.

6. A lift station pumps wastewater with a specific gravity of 1.01 against a 35 ft. head. Calculate the motor horsepower necessary if the flow rate is 1200 GPM, pump efficiency at 55% and motor efficiency 90%.

7. Calculate the horsepower needed to pump water at a rate of 210 GPM against a total head of 42 ft.

Module No:	Module Title: Advanced Mathematics
	Submodule Title:
Approx. Time: 1 hour	EVALUATION

Objectives:

The learner will be able to demonstrate the ability to determine correctly the answers to 8 out of 10 problems related to:

a. Flow measurement

b. Flow in pipe

c. Total head

d. Pump and motor power efficiency

1. If the pressure in a water main is 65 psi, what is the minimum loss in water pressure at a water faucet 25 ft. above the main.

   a. 57.7 psi

   b. 54.2 psi

   c. 10.8 psi

   d. 7.3 psi

2. A horizontal section of pipe has two diameters, the first is 18 inches and the second 12 inches. If the flow rate through the 18 inch pipe is 165 gallons per second, calculate the velocity through the 18 inch pipe.

   a. 12.5 ft/sec.

   b. 39 ft/sec.

   c. 0.65 ft/sec.

   d. 2.9 ft/sec.

3. Using the nanogram determine the discharge in GPM from an 8" pipe with a velocity of 3.5 ft/sec.

   a. 500 GPM

   b. 900 GPM

   c. 1.8 GPM

   d. 800 GPM

4. A 6" sewer line flowing ½ full with a velocity of 1.8 ft/sec. Calculate the rate of flow.

   a. 18 ft^3/sec.

   b. 1.4 ft^3/sec.

   c. .35 ft^3/sec.

   d. 0.18 ft^3/sec.

5. A venturi meter has a throat of 2 inches and an inlet of 3½ inches. Calculate the k for the meter. Pressure gauges read in psi.

   a. 4.4

   b. 9.09

   c. 9.364

   d. 3.364

6. A cipolletti weir is placed in an open channel. If the length of the weir opening at the base is 4 ft. and the head is 14.4 inches, calculate the flow rate.

   a. 114.05 ft^3/sec.

   b. 12.06 ft^3/sec.

   c. 743.6 ft^3/sec.

   d. 17.7 ft^3/sec.

$Q = 3.367\ LH^{1.5}$

7. Using the pump curve provided, what is the GPM delivered against a 48 ft. head using a 7" impeller.

   a. 1380

   b. 1210

   c. 1200

   d. 1190

8. Calculate the BHP of the pump if the pump efficiency is 85%.

   a. 19 Hp.

   b. 23 Hp.

   c. 16 Hp.

   d. 56 Hp.

9. Calculate the cost of operating the pump for one day if the cost/kwh is 6 cents.

   a. 9.76

   b. 35.25

   c. 14.25

   d. 12.73

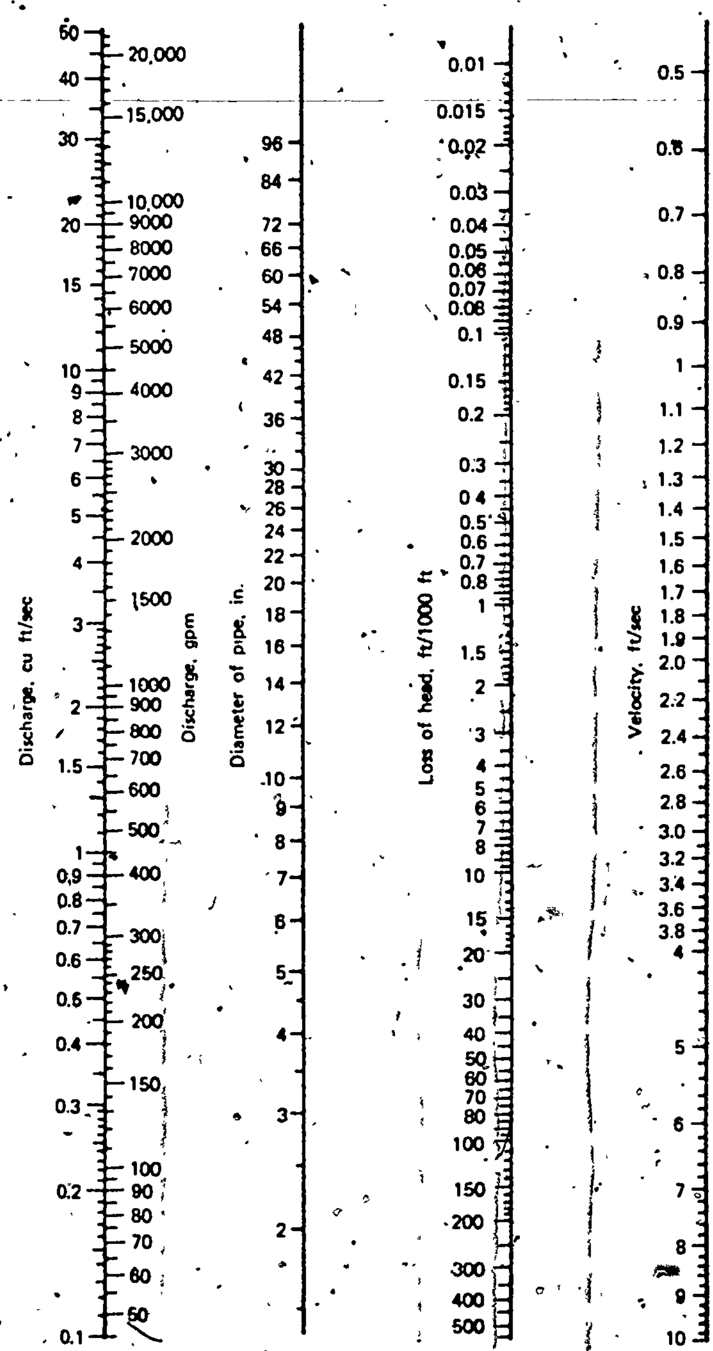
10. Records indicate that the pump efficiency has decreased to 79%. What is the additional cost in operating the unit for a day.

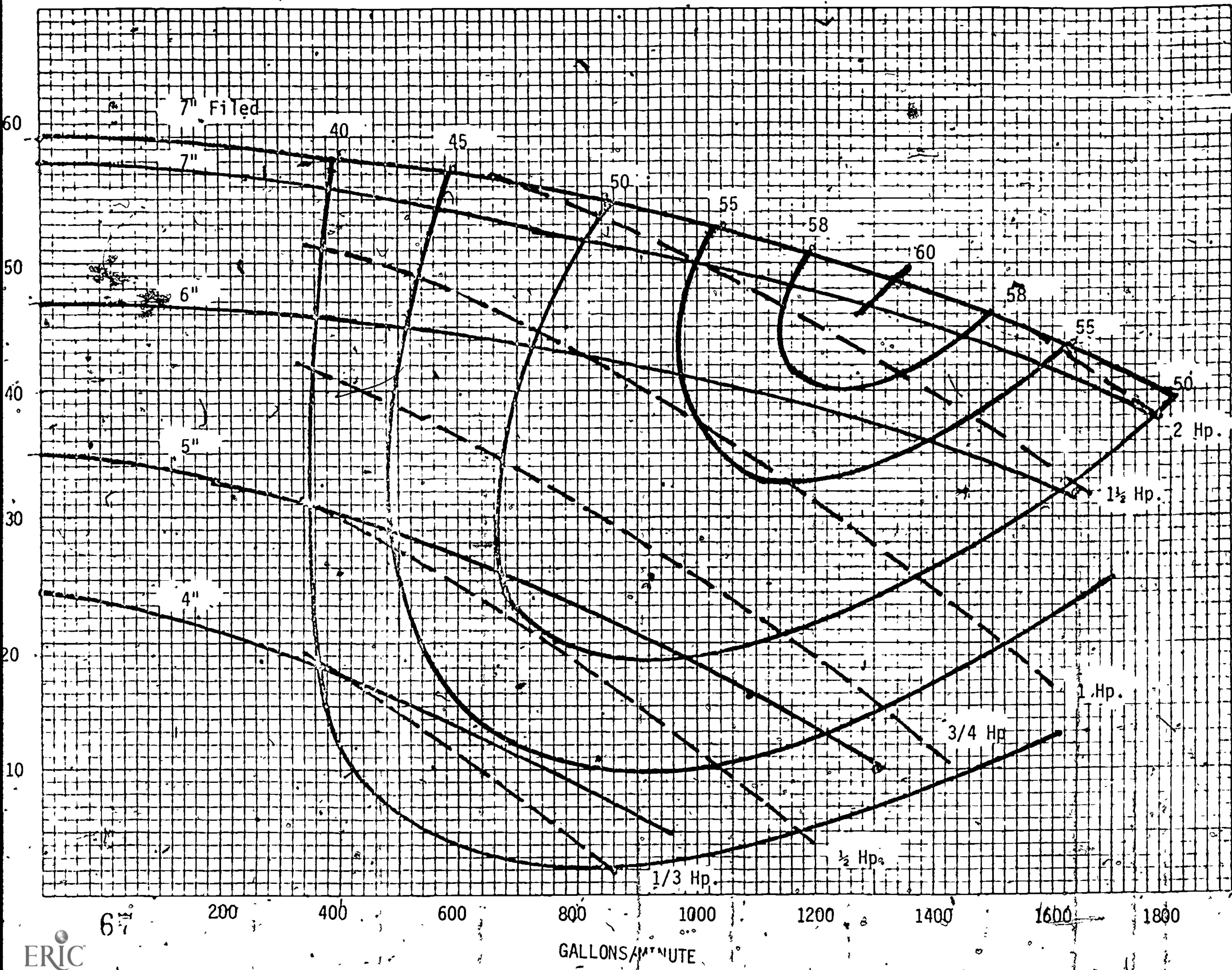
    a. 117 cents

    b. 265 cents

    c. 97 cents

    d. 513 cents


Discharge, cu ft/sec
Discharge, gpm
Diameter of pipe, in.
Loss of head, ft/1000 ft
Velocity, ft/sec



7" Filed
7"
6"
5"
4"
40
45
50
55
58
60
58
55
50
2 Hp.
1½ Hp.
1 Hp.
3/4 Hp
½ Hp.
1/3 Hp.
60
50
40
30
20
10
200
400
600
800
1000
1200
1400
1600
1800
GALLONS/MINUTE

Module No:	Topic: EVALUATION

Instructor Notes:	Instructor Outline:
Answers 1. c 2. a 3. d 4. d 5. a 6. d 7. d 8. b 9. d 10. c	Give 10 evaluation problems